AIR TRANSPORTATION OF FRUITS, VEGETABLES AND CUT FLOWERS: TEMPERATURE AND HUMIDITY REQUIREMENTS AND PERISHABLE NATURE

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Air Transportation of Fruits, Vegetables and Cut Flowers: Temperature and Humidity Requirements and Perishable Nature. 1/

This report has been prepared to fill a need for information on the perishable nature of fruits, vegetables and flowers, why they must be handled as perishable freight and what temperatures and humidities are best for their transport by air. It covers the results of experimental work reported elsewhere and general experience of workers in the field of storage and transportation. Air transporation holds forth a promise of making it possible to ship high quality, freshly picked fruits, vegetables and flowers to the consumer. By means of it, varieties possessing superior qualities, too perishable to ship by land or sea may be given more than local distribution, and standard varieties may be picked more nearly at a peak of perfection than is possible when slower modes of transporation are used. All of the advantages of speed can be lost if the shipper, carrier and receiver do not follow good handling practices that keep deterioration to a minimum.

From the standpoint of the perishable cargo, the airplane offers only the advantage of speed. Conversely it seems to offer few physiological problems peculiar to the fact that the commodity is being flown through the air. The intent here is to present information regarding the handling requirements of perishables in air transit. Following a discussion of principles and general information, fruits, vegetables and flowers are discussed separately and in detail. The economic aspects of the movement of perishable cargo by air are not considered and many products are included which have no air freight potential at present.

FRESH PRODUCE IS ALIVE

All fresh fruits, vegetables, and cut flowers are alive and remain living throughout their entire period of salability. Being alive, they respond to the environment in which they are held and have fairly definite limitations as to the conditions that can be tolerated. They remain alive by utilizing reserve "foods" that were stored during growth. The process of breaking down stored food into energy, carbon dioxide, and water, with the uptake of atmospheric oxygen, is known as respiration. Respiration together with accompanying chemical changes results in changes of quality and eventual death of the commodity. These internal changes associated with life cannot be stopped but should be retarded if quality is to be retained at a high level for a prolonged period.

The goal of good handling and shipping practices is to provide environmental conditions that will result in minimum deterioration and yet keep the perishable commodity alive and healthy.

1/ Prepared by a committee of the Air Cargo Institute of California. Although all sections were edited jointly, the responsibility for preparation was divided as follows:
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TEMPERATURE REGULATES DETERIORATION

Of the environmental factors subject to control, refrigeration is the most practical method of slowing deterioration. Within the temperature range usually encountered, the rate of deterioration of fruits, flowers, and vegetables is increased from two to four fold for each 18°F. (10°C) rise in temperatures. Thus the rate of deterioration at room temperature may be five to ten (or more) times as fast as the rate at 32°. On a hot day, deterioration may be progressing twenty or thirty times as rapidly as under proper refrigeration. More deterioration can take place in one day under hot conditions, 85° and above, than would occur in a month or more at 32°. It is apparent, that a perishable commodity might deteriorate more during a warm plane trip of a few hours than it would during several days in a well refrigerated surface conveyance.

The effect of temperature upon deterioration is shown by the following observations obtained with spinach. With certain limitations, this relationship applies to all vegetables, flowers and fruits.

EFFECT OF TEMPERATURE ON RATE OF DETERIORATION (Spinach 1/)

Temperature °F.	Storage Life Days	Rate of Deterioration Relative to that at 32°F.
32	66	1
41	42	1 1/2
50	13	5
59	7	9
68	4	16
77	3	21
86	2	31

Not only does high temperature accelerate ripening, respiration, and deterioration, but it also favors the development of decay. Decay may terminate the usability of certain perishables such as ripe fruits long before the product would have deteriorated otherwise. The activity of the organisms causing decay is accelerated by temperature in the same way as the respiration of the produce; thus temperature reduction becomes doubly important.

Chilling Injury. The maintenance of temperatures near 32°F. is not desirable for all products as some are subject to chilling injury when exposed to temperatures well above this point. Chilling injury is most pronounced in horticultural products of tropical ancestry such as bananas, tomatoes, cucumbers, avocados and orchids. Chilling results in a shortened storage life and may be evidenced by surface blemishes, internal discoloration, failure to continue normal ripening processes, increased susceptibility to decay, and, in the case of flowers failure to develop normally. The temperature and length of exposure required to cause injury varies with the commodity and perhaps with prior growing conditions. Temperatures above 55° are usually safe for cold sensitive commodities. The relatively short time in air transit is unlikely to be long enough to cause serious trouble except, perhaps, with certain flowers and tropical foliage. However, exposure of cold sensitive commodities to chilling temperatures should be avoided.

1/ Unpublished data--Univ. of Calif.

Precooling. It can be stated as an axiom that perishables harvested at table maturity should be cooled to recommended holding temperature as soon as practicable. Thus deterioration is retarded at the earliest possible time. Cooling prior to shipment is commonly termed precooling and is accomplished by the use of cold air, cold water, direct contact with ice, or the recently developed vacuum cooling method. All methods of precooling are not applicable to all perishables. Care is needed to insure adequacy of cooling and maintenance of low temperature between cooling and loading. Precooling takes on additional significance in relation to air shipments. The high perishability of certain products make precooling essential and lack of refrigeration on the plane makes precooling valuable under nearly all conditions. Perishables that have been properly precooled usually remain in a desirable temperature range during a flight of a few hours if protected from warm air. However, refrigeration in transit may be essential for products having high respiration rates, flowers for example, even though they are well cooled at the time of loading.

Self-Heating of Cargo. Most of the energy that a product liberates as a result of respiration is in the form of heat. This "vital heat" is important because it may produce an undesirably high product temperature. If the heat is not dissipated, a spiralling process of increasing temperature, accelerated respiration and rapid deterioration result. As a general rule, fast growing, highly perishable vegetables, flowers and fruits are the ones that produce large quantities of heat that must be dissipated. Certain vegetables such as peas, broccoli, spinach, snap beans, lettuce and sweet corn have high respiration rates and the heat produced may amount to the equivalent of 250, or more, pounds of ice meltage per ton of vegetables per day at 60°F. Fruits, in general, have lower respiration rates, but berries liberate rather large amounts of vital heat. Self-heating of flowers is probably most pronounced with the more perishable types and those with heavy foliage.

A tabulation of the heat of respiration for many fruits and vegetables is given in U. S. D. A. Circular 278. The prevention of self-heating of the product has an obvious relation to refrigeration, precooling, ventilation, type and size of package, and stowage.

Temperatures During Flight. An airplane is necessarily exposed to wide extremes in outside air temperatures which vary with the altitude, latitude, time of day, and season of the year. Although a threat of freezing exists, especially during the colder periods of the year the maintenance of desirably low product temperatures is a greater problem. Usually, high altitudes do not assure desirably low product temperatures during transit. The following are a few observations of outside and inside temperatures during flight. In a test trip from San Francisco to Reno in March 1/, outside temperatures at ground level, 9,000, 15,000, 18,000, and 25,000 feet were 65°, 32°, 0°, -14°, and -48°F., respectively. This drop in temperature with increasing altitude exceed the theoretical rate of slightly more than three degrees for each 1,000 feet of climb and yet the temperature 12 inches from the wall in an unheated cargo compartment did not drop below 32° during the two-hour climb. On the return trip, during 1 1/2 hours at 12,000 feet with an outside temperature 20°, the air in the cargo compartment cooled only one degree - from 53° to 52°. The inner surface of the floor and wall of the plane cooled much faster than the air 12 inches away. During the first hour of the trip the floor and wall surface cooled to 34° while the plane was ascending to the 18,000 ft. level and to 7° and 17° respectively during the next hour of climb to 25,000 feet. In 1 1/2 hours a constant level of 12,000 feet and 20°

1/ Barger, W. R. and W. T. Pentzer, Report of Test Shipment of Cut Flowers from San Francisco, by Air Express, March 14, 1941. U. S. Bureau Plant Indus., Soils, Agr. Engin. Div. Fruit and Veg. Crops and Diseases. H. T. & S. Office Report 65. 1941

outside temperature, the floor and wall temperature were reduced only 5 and 3 degrees respectively from an initial temperature of about 50°.

Temperature records have been obtained in a number of flights between San Francisco and eastern terminals. During a flight in November the temperature in the cargo compartment did not go below 40°F. during the 4 1/2 hour period between Sacramento and Denver even though the outside temperature was between 18° and 25°. In June, July, and August the temperature inside the plane rarely was below 60° in flight and occasionally reached 80° during ground stops.

Records of flights between Hawaiian Islands and San Francisco 2/ show an average outside temperature of about 50°F. at 8,000 to 9,000 ft. altitude in March and April, about 63° in August and September and prevailing temperatures below 50° only during the winter months.

Control of Product Temperature. The temperature of a perishable commodity during air transit will be affected by the air temperature in the cargo compartment; the initial commodity temperature; the nature of the package and other insulating material used; the method of loading; the physical nature of the product; and the heat produced by the product. The need for control of the product temperature begins before delivery to the carrier and extends beyond delivery. The role of precooling has been discussed above. Insulated delivery trucks and refrigerated holding space at, or near, the airports at each end of the trip are desirable. More information is needed regarding methods of obtaining suitable temperatures during transit by air.

It has not appeared feasible to put mechanical refrigeration on cargo carrying planes. At present, it seems more practical to obtain the desired temperature before shipment and then protect the commodity against undesirable temperature changes during and after transit by means of insulated compartments, load blankets and special shipping cases. Supplemental refrigeration such as package icing is probably essential for some highly perishable commodities.

The commodity temperature lags behind that of the air. In summer shipments, the cooling of unprotected commodities while aloft may be more than offset by the warming that occurs during ground stops. The air temperature in a plane parked in the sun may be several degrees above that of the outside air. In shipping tests, dry pack lettuce has warmed several degrees during a transcontinental trip from the West Coast despite periods of cooling while in flight between stops.

The lower temperatures likely to occur near the wall and floor of non-insulated compartments make it desirable to stow the cargo away from these surfaces during cold weather. The desirable cooling that one would get during summer flights by stowing near the skin of the plane would be offset by the more rapid warming during ground stops.

The use of auxiliary insulating blankets to prevent undesirable changes in the temperature of cut flowers has been tested under simulated flight conditions. 3/ A fiberglass blanket and floor pad (approx. 1" thick and weighing.215

2/ From Captain Robert Moorehead, Consair Pilot.

3/ Barger, W. R. and A. Lloyd Ryall. Air Cargo Insulation Studies with Flowers. U. S. Bur. Plant Indus. Soils, Agr. Engin. Div. Fruit and Veg. Crops and Disease. H. T. & S. Office Report 225. 1950.

lbs/sq/ft) prevented a block of 12 boxes of cut flowers from freezing during 7 hours when the surrounding air was about 0°F. and the pressure approximated that at 20,000 ft. altitude. The blanket also proved valuable in retarding the warming of cooled flowers when exposed to an air temperature that reached 95°. These trials also included various insulating box liners. A thin aluminum foil liner seemed to be more effective against freezing than newspapers or other pad type insulating materials. The wetting of paper liners by moisture within the packages undoubtedly reduced their insulating value.

Light weight shipping cases designed to carry 50 lbs. of strawberries and a small amount of dry ice for supplemental refrigeration have been used. 4/ Tests 5/ indicate that desirably low transit temperatures for precooled strawberries can be maintained in these containers.

WATER LOSS

Horticultural products high in moisture content tend to lose water by evaporation after harvest. If not controlled, water loss may result in serious wilting and a loss of fresh appearance, quality and salable weight. The rate of drying is determined by the temperature of the product, the temperature and relative humidity of the atmosphere, the extent of air movement, the atmospheric pressure, and the nature of the product itself. Fortunately water loss usually can be minimized by control of the relative humidity of the air. It should be maintained between 85 and 95 percent. Partial control of humidity is afforded by the package or, in the case of flowers, by adding moisture to the package. There is less water loss if the product is kept cool. The application of a film of wax will retard the rate of water loss. Waxing is commonly practiced on tomatoes, cantaloups, citrus fruits, and cucumbers. Exposure to high temperatures, low humidities, excessive air movement, or sunshine should be avoided at all times.

The control of the relative humidity is especially important during flight. Records taken during transcontinental flights show that the relative humidities in the cargo compartment over mountainous areas were 15 to 20 percent during June and July and about 40% during November. Over the Great Plains the humidities were higher but usually below 50 percent even at altitudes as low as 5,000 ft. Not only is the rarified air at high altitude very low in water content, but the reduced air pressure accelerates the rate of water loss from the product. Since the rate of water loss is inversely proportional to the air pressure; the rate of water loss at 10,000 ft. altitude theoretically would be nearly 50 percent greater than at the same vapor pressure deficit at sea level.

MATURITY AND QUALITY

With many products, especially fruits, the maturity that results in the best eating quality is too advanced for the fruit to carry satisfactorily for a long-distant surface haul. Thus there is often a compromise between carrying quality and eating quality. Little or no compromise should be necessary for products properly handled as air cargo. Therefore, where advanced maturity adds to the quality of the product, growers and shippers who ship by air should attempt to market only fruits of such premium quality. The standards now used to evaluate

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4/ Mr. Charles T. Wrightson, Station Mgr. United Air Lines, Fresno, Calif. has been instrumental to this development.

5/ Barger, W. R. Refrigerated Strawberry Cases. Modern Packaging 14: 125, 126, 173, 175. Nov. 1950.

shipping maturity for some fruits will have little direct application to air-borne perishables. Special procedures directed specifically toward the production and handling of products destined for air shipment may be necessary. In fact, in some cases, the varieties best suited for air shipment may be different from those usually produced for rail shipment. Furthermore, the carrier must exercise care and provide desirable conditions for these more perishable types.

EFFECT OF REDUCED AIR PRESSURE

Considerable concern has sometimes been expressed regarding possible damage to commodities subjected to the lower atmospheric pressures prevailing at high altitudes. Recent tests by the U.S.D.A. and Lockheed research personnel indicate that injury from this source is extremely unlikely. 6/, 7/, 8/, 9/

Of 34 different fruits and vegetables tested in a large decompression chamber having temperature and humidity control and capable of simulating flights up to 50,000 ft. altitude, no injury occurred that could be attributed to the effects of altitude up to 30,000 ft. or to the effects of rapid climb or descent up to 3,000 ft. per minute. In an extremely severe test simulating a climb of 5,000 ft. per minute up to 50,000 ft. altitude, splitting occurred only in some ripe tomatoes and persimmons at about the 45,000 ft. level.

With commercial packs of cut flowers tested in the same way, no injury to blooms or ill effect on normal opening of buds occurred at altitudes up to 20,000 ft. Carnations, roses, sweet peas, and mums showed slight and moderate withering at the edge of the petals after simulated flights to 30,000 ft. and 50,000 ft. altitudes, respectively, indicating that flowers are somewhat more sensitive to low vapor and air pressures prevailing at high altitudes than are the more fleshy fruits and vegetables. As noted above, reduced air pressure results in a proportional increase in the rate of water loss from the commodity.

EFFECT OF ONE COMMODITY UPON ANOTHER

Fruits produce and give off volatile emanations as they ripen. Ethylene is one of the products evolved and it has been demonstrated repeatedly that very small concentrations hasten the ripening of fruits and the deterioration of cut flowers. Other sources of ethylene include illuminating gas and the exhaust fumes from gasoline engines.

6/ Barger, W. R. Effects of Changes in Atmospheric Pressure in Fruits and Vegetables. U. S. Bur. Plant Indus. Soils and Agr. Engin. Div. Fruit and Veg. Crops and Diseases. H. T. & S. Office Report 197. 1948.

7/ Barger, W. R. Altitude Tests with Flowers. U. S. Bur. Plant Indus. Soils, and Agr. Engin. Div. Fruit and Veg. Crops and Diseases. H. T. & S. Office Report 224. 1950.

8/ Hackney, L. R. and B. A. Rose. Altitude tests on Fruits and Vegetables. Lockheed Air Cargo Progress Report SLR824. 1949.

9/ Della-Vedowa R. P. and B. A. Rose. Altitude Tests on Flowers. Lockheed Air Cargo Progress Report SLR 942. 1950.

It seems doubtful that ethylene presents a problem peculiar to air transit of fruits and vegetables. Most mature fruits probably would not be affected by conditions normally encountered. The effect of ethylene is minimized by the maintenance of desirably low temperatures. However, confining immature "fruits" such as cucumbers and green peppers in the same space with mature fruits should be avoided when practical. Exposure of any product to engine exhaust should be minimized or prevented.

Since many flowers are known to be very sensitive to ethylene, this factor should be given consideration. They "go-to-sleep", wither prematurely, and age rapidly when exposed to ethylene or when stored in the same room or even in the same building with apples, 10/ and probably other fruits such as oranges, peaches, and pears. Roses, carnations, snapdragons, stocks, and daffodils are affected in a short time. Holly drops its leaves prematurely and probably most other florists' greens and foliage are injured also. It would seem undesirable to ship flowers with ripe fruits or melons. Vanda orchids present special problems in handling which appear to be due to their extreme sensitivity to ethylene. Flowers of desirable maturity have been found to fade and age rapidly when packed with aging blooms. Tests have shown that the harmful volatiles can be removed from closed packs of Vanda orchids by including brominated activated charcoal. 11/

POST HARVEST TREATMENTS

Various post harvest treatments are applied to horticultural products, sometimes out of necessity and sometimes in the hope of reducing the rate of deterioration. These treatments, including various washes, waxes, gases and special packages, should not be considered as substitutes for careful handling and proper refrigeration.

Fumigation or insecticidal treatments may be necessary in order to move produce from quarantined areas. The effects of such treatments are, in general, harmful and they increase the importance of good handling practices.

Prepackaging of certain products may be somewhat helpful in reducing deterioration but does not change the general recommendations as to handling and temperature requirements.

NEED OF CAREFUL HANDLING

The importance of careful and correct handling mentioned before cannot be overemphasized. Even though the airplane may provide a faster, smoother ride for produce than surface conveyances, this in itself does not assure better delivered quality. Perishability of many products harvested at advanced maturity for shipment by air will be greater than for those of less advanced maturity moving by other means. Furthermore, advanced maturity coupled with lighter packaging increased the susceptibility of the product to damage by rough handling.

10/ Wright, R. C. et al. Some Effects of Apples and other Fruits on the Storage Life of Cut Flowers. Ice & Refrig. 100° 149-150. Feb. 1941.

11/ Lindner, R. C. Studies on Packaging and Storage of Vanda (Joaquim) Flowers. Hawaii Ag. Exp. Sta. Progress Notes 49. 1946.

The delivery of sound, high quality produce is one of the important benefits of air transit. Good handling practices, including proper packaging, must start in the field and carry through all subsequent operations to the consumer.

Experience in other fields of transit points to the fact that personnel must be instructed in the proper handling and stowing of produce. Perishables cannot be mixed with general freight without likely damage to the perishables.

FRUIT CROPS

Important Considerations Pertaining to Fruits

1. Fruits are alive.

2. They deteriorate after harvest by natural prccesses or as a result of decay.

3. Rapid cooling of the fruit and maintaining it at a cool temperature by refrigeration will retard deterioration and decay. Certain fruits such as the banana and papaya are injured by low temperatures and are exceptions to this statement.

4. Excessive water loss causes shrivelling and greatly reduces the value of a product. Maintenance of a fairly high relative humidity (85-90%) is desirable even during a one to two day holding or transit period.

5. There is no substitute for careful handling. Rough handling results in bruising thereby reducing appearance and quality and gives ready access to the entrance of decay organisms.

6. Only well matured high quality fruits should be shipped air.

Recommendations for Fruits

Commodity	Recommended transit temp. 1/ °F.	Permissible temp. for 48 hrs. °F. 2/	Perishability 3/
Apples	31-32	up to 50	Very low
Remarks: It is unlikely that this fruit will be shipped extensively by air. No important problems are apparent.			
Apricots	31-36	up to 45	Moderate 4/
Remarks: This fruit is normally harvested at such an immature stage for eastern shipment that premium quality is not obtained. For air shipment it could be harvested near the tree-ripe stage and a high quality product made available to the consumer. Bruising is a problem with mature apricots. Decay from brown rot may be a serious problem if infection is present in the orchard. It is suggested that only varieties of top dessert quality such as Royal (also called Blenheim) be shipped by air. High quality fruit is considered to have good air cargo potential.			
Avocados	45-50	40-60	Moderate
Remarks: There are no particular problems with this fruit for the short period involved in air transit. Well matured fruits require several days to ripen after harvest so that advantages of air transit do not seem great.			
Bananas	55-60	55-60	Moderate
Remarks: Bananas are highly susceptible to chilling injury at temperatures below 55°F. Such injury greatly impairs the appearance of the fruit and interferes with subsequent ripening. Air potential to areas now supplied by surface transportation seems small.			
Berries			
Blackberries	31-32	up to 40	High 4/
Raspberries	31-32	up to 40	High 4/
Strawberries	31-32	up to 40	High 4/
Remarks: Berries including blackberries, boysenberries, raspberries and strawberries are perhaps the most perishable of the fruits. Because of their short after-harvest life it is extremely important that their history be known, both as to conditions in the field in which they were grown and also conditions after harvest. Strawberries are often infected in the field with various fungus diseases and may show serious decay within 24 to 48 hours after harvest. This is especially true shortly after rains or			

1/ The freezing points of most fruits range between 28 and 30°F.

2/ This represents a conservative figure and is based on the assumption that the product temperature remains in the range indicated. Obviously, a well packaged fruit can withstand short exposure to temperatures well below or above this range. The assumption is made that the fruit would be in the hands of the retailer at the end of the 48 hour period and that a condition to be classed as "good" is essential at time of delivery to the retailer.

3/ Relative perishability, high - not stored commercially; moderate - stored or in transit for periods not exceeding 2 weeks; low - may be stored commercially up to several weeks; very low - may be stored commercially for several months.

4/ Indicates that decay may be a serious problem.

Commodity	Recommended transit temp. 1/ °F.	Permissible temp. for 48 hrs. °F. 2/	Perishability 3/

after a field has been irrigated. The drupelets of blackberries, boysenberries and raspberries are often injured in the process of harvesting and packing. The injury and exuded juice makes an excellent place for the growth of various decay organisms. Rapid cooling and fairly high humidity are important factors in satisfactory handling of these fruits. Fruits must approach full maturity and ripeness on the vine for top quality. Considered to have good air cargo potential for markets without a nearby supply.

Cherries, Sweet — 31-32 — up to 40 — Moderate 4/

Remarks: Cherries may deteriorate by becoming overripe as indicated by a black color or they may be infected with brown rot, especially following periods of rainy weather. Rapid precooling and high humidity are very important in handling this fruit. Considered to have fairly good air cargo potential for top quality fruit.

Cranberries — 35-40 — up to 70 — Very low

Remarks: There is no particular problem involved with this fruit. Normal air cargo potential considered to be very low.

Figs — 32-36 — up to 45 — High 4/

Remarks: Figs are of the best quality when harvested fully mature. At this stage they are somewhat soft, and care must be taken to avoid bruising. The flesh is very tender and subject to decay. Rapid cooling is desirable. It is believed that the fig may develop a high air cargo potential after distant consumers have become familiar with it.

Grapes, vinifera — 31-32 — up to 50 — Low to very low

Remarks: Ordinarily there is no particular problem with this fruit. Following rainy periods, however, Botrytis rot may be damaging. Care should be taken in handling to prevent the berries' shattering from the clusters. Except for limited shipments of early grapes movement by air will probably be small.

Grapefruit — 40-45 — up to 70 — Low

Remarks: There are no particular problems involved with this fruit. Considered to have little or no air cargo potential.

Lemons — 55-58 — up to 70 — Very low

Remarks: There are no particular problems involved with this fruit. Considered to have little or no air cargo potential.

Limes — 45-48 — up to 60 — Moderate

Remarks: There are no particular problems involved with this fruit. Considered to have low air cargo potential.

Commodity	Recommended transit temp. 1/ °F.	Permissible temp. for 48 hrs. °F. 2/	Perishability 3/
Oranges	32-40	up to 70	Low
Papaya	55-60	45-65	High to moderate
Peaches, freestone and nectarine	31-32	up to 45	Moderate 4/
Pears	31-32	up to 50	Low to very low
Persimmons	32-34	up to 50	Moderate
Pineapple	42-45	40-60	Moderate

Remarks: There are no particular problems involved with this fruit. Considered to have little or no air cargo potential.

Remarks: Papayas, especially at the green mature stage are subject to chilling injury when held below 50°F. Fruits from areas where quarantine treatments are required before shipment are more susceptible to injury and decay than untreated fruits. This fruit is extremely tender and bruised areas do not ripen properly. Considered to have good air cargo potential.

Remarks: Freestone peaches and nectarines for air shipment should be at a more advanced stage of maturity than those shipped by rail. Such fruit will be softer and will require more careful handling to avoid bruising. Rapid precooling and holding at a comparatively low temperature is desirable to slow up ripening changes and reduce the possibility of decay from brown rot. Only varieties of high dessert quality should be shipped by air. Top quality fruits of varieties selected for high quality are considered to have good air cargo potential.

Remarks: There is no particular problem with this fruit unless it has been allowed to ripen prior to shipment. Ripe pears are highly perishable and will keep for only a few days even at low temperatures. Seckel, a small, early, high quality variety may be well adapted to air transit. Gift package pears of varieties such as Comice may also be well adapted to air transit. Other pears are considered to have little or no air cargo potential.

Remarks: A reduced temperature is not greatly effective in slowing up the rate of softening of this fruit. It should be handled, therefore, only early in the season while still in firm condition. After it becomes soft it is very tender and highly perishable. This fruit may become a fair air cargo potential if it becomes better established in distant markets.

Remarks: Pineapples, especially those on the green side at harvest are subject to chilling injury below 40°F. Desirable fruit for air cargo should be of advanced maturity. Considered to have fairly good air cargo potential.

Commodity	Recommended transit temp. 1/ °F.	Permissible temp. for 48 hrs. °F. 2/	Perishability 3/
Plums	31-32	up to 45	Moderate to low 4/

Remarks: Plum varieties vary greatly in their storage life. Most of the Japanese plum varieties are harvested before they reach a stage of maturity for highest quality fruit. Plums for air shipments should be allowed to approach a tree-ripe stage before harvest so that the consumer may receive a product much superior in quality to that which can be shipped by rail. Only fruits of varieties of high dessert quality should be shipped. Such fruit is quite perishable and may be subject to the attack of brown rot. Rapid precooling and a low holding temperature is desirable. Only top quality fruits of high dessert quality are considered to have air cargo potential.

Tangerines	32-40	50	High to moderate

Remarks: Very susceptible to decay as they become tree-ripe. Need precooling and low holding temperatures.

VEGETABLE CROPS

Important Considerations pertaining to Vegetables

1. If the vegetable is composed largely of leaves, stems or immature flower parts, then it is likely to be highly perishable. Wilting, yellowing, and decay cause rapid deterioration. Temperatures near 32°F., high relative humidity, (above 85 per cent) and protection from the sun and wind are desirable. Precooling is essential when there is much field heat.

2. If the edible portion is an immature seed such as peas, sweet corn, or lima beans, it is also likely to be highly perishable. Low temperature, high relative humidity and protection from sun and wind are essential for these vegetables. Prompt precooling and maintenance of temperatures below 50°F. are absolutely essential even for periods involved in plane transit.

3. Immature fruit such as cucumbers, summer squash, green beans, or eggplant, are likely to be moderately to highly perishable. A temperature below 50°F. is often undesirable when prolonged more than 48 hours. Howver, no chilling injury is likely to occur in a usual plane trip.

4. The perishability of mature fruit such as tomatoes, cantaloupes, watermelons, or squash will depend upon the degree of maturity and the type of natural peel that it possesses. Flight and holding temperatures ranging from 32°F. to 65° to 70°F. can be tolerated if maturity is given proper consideration.

5. The perishability of Root or similar types of vegetables is usually low. A cool moist condition is recommended. Sweet potatoes are an exception and should not be exposed to temperatures below 55°F. Root vegetables that are bunched with their tops attached should be considered as leafy in nature.

6. Trimming, segmenting, husking, and shelling usually increase the perishability of the vegetable concerned. Vegetables prepared in this way should be handled as highly perishable. Consumer packaging is unlikely to have any practical effect other than affording protection against water loss.

7. Vegetables contain a large amount of water and many of them are not well protected with peel or rind. Thus careful handling, protection from the sun and wind, and careful stowage in the plane are of importance.

8. Many vegetables are subject to self heating because of their high respiration rates. Thus, in many cases, provision for dissipation of the heat of respiration is essential.

9. The freezing temperature of most vegetables is approximately 31°F. The length of time necessary to cause freezing injury will depend upon the temperature, the exposure time, and the type of package.

Recommendations for Vegetables

Vegetables	Recommended transit temp. 1/ °F.	Permissible range for 48 hr. period 2/ °F.	Perishability 3/
Artichoke, Globe	32	32 to 50	Moderate
Remarks: Keep dry. Protect from sun and wind. Should present no special problems. Air shipment appears to offer but little advantage.			
Asparagus			
Bulk package or prepackaged	32	32 to 40	Very high
Remarks: Precooling desirable. Expedient handling and dissipation of heat produced by product essential. Wilting, yellowing, toughening and loss of flavor are the main problems. Keep tips dry and protect them from mechanical damage. Attention and care needed from field to consumer. Only first of crop likely to move by air.			
Beans			
Snap, (Bulk package or prepackaged)	45	32 to 50	High
Remarks: Precooling desirable. Expedient handling and dissipation of heat produced by product essential. Avoid large packages to prevent heating. Keep beans dry. Avoid over-maturity. Only out of season crop likely to be shipped by air.			
Beans			
Lima, in pod	45-50	32 to 50	Moderate
Remarks: Keep dry. Avoid large packages.			
Shelled	32	32 to 40	Very high
Remarks: Keep dry. Dissipation of heat essential. Use only small packages. Precooling desirable. Very likely to present problems. Out of season crop might offer possibilities for air shipment.			

1/ This represents the temperature at which minimum deterioration will occur--Source U.S.D.A. Circ. 278 and personal experience.

2/ This represents a conservative figure and is based on the assumption that the product temperature remains in the range indicated. Obviously, a well packaged vegetable can withstand short exposure to temperatures well below or above this range. The assumption is made that the vegetable would be in the hands of the retailer at the end of the 48 hour period and that a condition to be classed as "good" is essential at time of delivery to the retailer.

3/ Relative perishability: "very high" or "high" indicates that these vegetables have a market life of only a few days and will require expedient, careful, handling with attention to all details; "moderate" indicates a market life of about 2 weeks and these vegetables will ship with little or no trouble under desirable transit conditions; vegetables rated as "low" in perishability can be held up to several weeks and can withstand rather unfavorable conditions for short periods.

Vegetables	Recommended transit temp. 1/ °F.	Permissible range for 48 hr. °F. 2/	Perishability 3/
Broccoli, Sprouting	32	32 to 40	Very high
Remarks: Heat generated must be dissipated. Expedient handling essential. Wilting and yellowing are most severe defects. Precooling essential unless product is cold. Air shipments seem to offer little advantage.			
Beets, (see Carrots)			
Brussels Sprouts Bulk package or prepackaged	32	32 to 50	High
Remarks: See remarks under Broccoli. Would benefit by air transit.			
Carrot, Bunched	32	32 to 50	Moderate
Remarks: Wilting and yellowing of tops are the most common defects. Protect from sun and wind. Not likely to be shipped by air.			
Topped	32	32 to 70	Low
Remarks: Shrivelling due to loss of water most common defect. Should present no serious problems. Not likely to be shipped by air.			
Cauliflower, Whole head	32	32 to 50	High
Remarks: See broccoli notes.			
Segmented curd	32	32 to 40	Very high
Remarks: Browning of cut surfaces is most common defect. Prepackaged cauliflower may offer economic possibilities.			
Celery, Bulk package or prepackaged	32	32 to 40	High
Remarks: Wilting and discoloration are the most severe defects. Removal of field heat is essential. Not likely to be shipped by air except perhaps as packaged hearts.			
Chayote (See cucumbers)			
Chicory, Witloof (Sometimes called Belgium endive)	32	32 to 50	Low
Remarks: Protect from wilting. May offer possibilities as air cargo.			

Vegetables	Recommended transit temp. 1/ °F.	Permissible range for 48 hr. period 2/ °F.	Perishability 3/
Chinese cabbage	32	32 to 60	Low
Remarks: Protect from wilting. Not likely to be shipped by air.			
Cucumbers	50	32 to 70	Moderate
Remarks: Subject to chilling injury. Do not expose below 50° longer than 48 hours. Protect from wilting. Waxing desirable. Might move by air from areas of winter production.			
Eggplant	50	32 to 70	Moderate
Remarks: Subject to chilling injury. Do not expose below 50° longer than 48 hours. Should present no special problems. Only out-of-season crop likely to be shipped by air.			
Endive, (Chicory type or Escarole type)	32	32 to 40	Moderate
Remarks: See lettuce. Air shipment would offer little advantage.			
Garlic, (complete bulbs or segmented cloves)	32	32 to 80	Low
Remarks: No special problems. Dry, well ventilated conditions necessary. Not likely to be shipped by air.			
Lettuce (Leaf, head or Romaine)	32	32 to 50	Moderate
Remarks: Protect from wilting. Objectionable reddening of cut surfaces may develop. Removal of field heat essential. Lettuce harvested following unseasonably hot weather often develops slime in transit. Air shipment would offer little advantage.			
Melons, Cantaloupes, Crenshaw and Persian	45	32 to 50	High
Remarks: Stage of maturity is most important factor. Should be firm-ripe. Cantaloupes should show full slip but be firm. First of crop and highly perishable types may offer possibilities as air cargo. Only high quality types should be given consideration.			
Honeydews	50	32 to 75	Moderate
Remarks: Stage of maturity important. Should be nearly table ripe. Precooling should not be necessary.			
Okra	50	32 to 40	High
Remarks: Subject to chilling if refrigerated for prolonged periods. Subject to wilting. Avoid large packages. Only first of crop could be shipped profitably by air.			

Vegetables	Recommended transit temp. 1/ °F.	Permissible range for 48 hr. periods 2/ °F.	Perishability 3/
Onions Green bunched	32	32 to 40	High
Remarks: Sliming of tops most common form or deterioration. Dissipation of heat essential--produces large amounts of heat. Not likely to be shipped by air.			
Bulbs	32	32 to 80	Low to high
Remarks: Immature, uncured early varieties are perishable. Mature, cured, late varieties are relatively non-perishable. No advantage in air shipment.			
Parsley	32	32 to 40	Moderate
Remarks: Prevent wilting. Sliming and yellowing main defects. Little advantage to air shipment.			
Peas, (In pod or edible podded)	32	32 to 40	High
Remarks: Handle rapidly. Keep cold. Starchiness is chief defect. Precooling is essential.			
Shelled	32	32 to 40	Very high
Remarks: Must be kept cold from time of shelling to consumer. Many problems involved. Might offer economic possibilities if deterioration can be controlled.			
Peppers, green	40-50	32 to 60	Moderate
Remarks: Should present no troubles. Only out-of-season crop likely to be shipped by air.			
Radishes Bunched	32	32 to 40	Very high
Remarks: See bunched carrots.			
Topped and prepackaged	32	32 to 40	Moderate to high
Remarks: Prevent wilting. Not likely to be shipped by air.			
Rhubarb	32	32 to 50	Moderate
Remarks: Wilting chief defect. Should present no serious problems. Air shipment would offer only slight advantage.			
Salad Mix	32	32 to 40	Very high
Remarks: Keep cold and moist. Development of bad flavors and discoloration are chief defects. Should be cooled immediately after packaging. Air transit would be of definite advantage.			

Vegetables	Recommended transit temp. 1/ °F.	Permissible range for 48 hr. period 2/ °F.	Perishability 3/
Spinach and other greens, (bulk packages or prepackaged)	32	32 to 40	High
Remarks: Similar to salad mix. Keep cold and moist. Packaging should be done soon after harvest. Careful sorting and careful handling during packaging essential. Air shipment would be advantageous with prepackaged spinach.			
Squash (Summer, Zucchini, etc.)	50	32 to 60	Moderate
Remarks: See cucumbers.			
Sweet corn (in husk or husked and packaged)	32	32 to 40	Very high
Remarks: Corn must be kept at a low temperature from field to consumer. Precooling and dissipation of heat during transit essential--produces large amount of heat. Maintenance of appearance is not sufficient. Conversion of sugar to starch is chief defect. First of crop and prepackage husked corn might move by air. Air transit should result in marked improvement of quality.			
Tomatoes			
Pink	50-60	32 to 60	High
Remarks: Overripeness is chief problem.			
Hard ripe	40-50	32 to 50	Very high
Remarks: Overripeness chief problem. Handle carefully. Under most conditions maturity should not exceed about half ripe. Vine-ripened out-of season fruits may offer possibilities.			
Vegetable Plants			
Warm season crops	55	45 to 55	Very high
Remarks: Subject to chilling, wilting, sliming, and yellowing. Do not expose below 45°F. Afford air movement around packages. Would benefit greatly from air transit.			
Cold season crops	40	32 to 55	Very high
Remarks: Subject to wilting. Keep cool, moist and afford air movement around packages. Would benefit from air transit.			

CUT FLOWERS

Important Considerations Pertaining to Cut Flowers and Florists' Greens

1. Most cut flowers are highly perishable, yet their salability depends as much on long life in the hands of the consumer as it does on good condition upon arrival at the market. Keeping them cool and moist and protecting them from freezing are the chief problems.

2. For shipment by air only well grown flowers not overly forced into bloom should be used.

3. Use rigid containers that will stand the necessary handling. Florist boxes for most cut flowers are given additional support by wooden cleats within the container. Flowers should be secured to the container. Special boxes, used for orchids, gardenias, and camellias, covered tightly with cellophane, need small perforations to prevent swelling and collapse with changes in atmospheric pressure. Stack in plane away from side walls and on floor-racks to prevent freezing in winter and overheating in summer. 12/ Containers should be made of wax treated paper or have a water-proofed liner to prevent water soaking from ice commonly placed in package as refrigerant. Use absorbent material such as newspapers or cellulose packing as wrapping material for ice. Waterproof bags are sometimes used for water ice. 12/

4. Flowers are often warm when picked. They should be cooled before packing if possible. Place packed flowers in 32° to 40° room for several hours before shipping in warm weather. Additional refrigerants such as small blocks of ice, flake-ice, frozen wet newspapers, Super-Ice (sawdust impregnated with chemicals, soaked in water and frozen) or dry ice are commonly used within the package to keep the flowers cool until they reach destination. Flowers must be protected from freezing by dry-ice, by providing an air space, between it and the flowers or use of insulating material. 13/

5. Freezing in winter can be prevented by wrapping package with newspaper (about 20 sheets an ideal amount) cellulose material (Kimpak) or insulating blankets such as Jiffy blanket or Insulpak. 14/

6. Flowers should not be exposed to engine exhaust or kept near fruits and vegetables that give off ethylene.

12/ Sherer, S. J. and Stohr, E. "Shipping flowers by air." Part 2 and 3 Shipping Containers. The Florists' Review May 11, June 8, 1950.

13/ Danielson, W. F. and Stohr, E. "Shipping flowers by air" Part 4 Refrigerants. The Florists' Review July 13, 1950.

14/ Sherer, S. J. and Miller, L. J. "Shipping flowers by air". Part 6 Protective Wrappings. The Florists' Review Feb. 22, 1951.

7. In the following list of optimum and permissible temperatures for flowers in air transit, the lowest temperature is based upon an assumption that, except for flowers known to be injured by chilling, most of them can withstand cooling to 32°F. which is 1 to 5 degrees above their freezing points.

8. Undoubtedly many flowers have been flown to market at much higher temperatures than those appearing in the table, but maintenance of the most favorable temperature for long display life is the best way to insure consistently good delivery of flowers to distant markets. The preservation of prime condition for maximum life in such highly perishable commodities demands special attention to temperature requirements and careful handling throughout the entire marketing operation by shipper, carrier, and receiver.

Recommendations for Cut Flowers and Florists' Greens

Commodity	Recommended storage temp. 1/ °F.	Permissible range for 48 hrs. 2/ °F.	Perishability 3/ Rating	Remarks
Cut Flowers				
Anemone	45	32-55	Very high	Short-lived regardless of temperature.
Anthurium	55	45-60	High	Bruising and wilting main defects. Desirable to keep stems in water. Subject to chilling injury below 45°.
Babysbreath	40	32-45	Very high	Short-lived regardless of temperature.
Bird of Paradise	45	45-55	High	Bruising and aging main defects. Desirable to cover stems with wet paper and to use ventilated cartons. Subject to chilling injury below 45°.
Bouvardia	40	32-50	Moderate	Protect from excessive drying.
Camellia	45	32-50	Moderate	Usually packed in cellophane wrapped carton cellophane verted to prevent bursting in flight. Tends to drop petals.
Calendula	40	40-50	High	Drops petals readily. Injured by chilling below 40°.
Calla	40	32-50	Low	Keeps best if stems are pulled and not cut.
Candytuft	40	40-50	High	Drops petals readily. Injured by prolonged chilling below 40°.
Carnation	33	32-40	Moderate	Must be kept cold and moist. Very sensitive to ethylene.

1/ Storage temperatures obtained from several sources including USDA Circular No. 278, U.S.D.A. H.T.&S. Office Report No. 224, and University of Hawaii Progress Notes.

2/ This range is an estimate of the extremes in temperature to which the flowers can be subjected for a short time without impairing their subsequent life for display. The rate of cooling or warming of packed flowers with respect to the outside air will be influenced by the size and type of shipping case and the method of packing the flowers.

3/ Perishability rated as to length of life at the recommended storage temperature is as follows: Very high, 2 to 4 days; High, 5 to 6 days: Moderate 7 to 10 days; and Low, usually 14 days or longer.

Commodity	Recommended storage temp. 1/ °F.	Permissible range for 48 hrs. 2/ °F.	Perishability 3/ Rating	Remarks
China-aster	40	32-55	Moderate	Dissipation of heat produced by product may be necessary.
Chrysanthemum	35	32-55	Low	Petal subject to drying. Dissipation of heat produced by product may be necessary.
Clarkia	40	40-50	High	Injured by prolonged chilling below 40°.
Columbine	40	40-45	Very high	Short-lived regardless of temperature. Injured by prolonged chilling below 40°.
Cornflower	40	35-50	High	Injured by prolonged chilling below 40°.
Crocus	33	32-50	Low	Probably sensitive to ethylene.
Daffodil	40	32-45	Low	Very sensitive to ethylene.
Dahlia	40	32-50	Moderate	Dissipation of heat produced by product may be necessary.
Daisy				
English	40	40-50	High	Injured by prolonged chilling below 40°.
Shasta	40	40-50	Moderate	Injured by prolonged chilling below 40°.
Delphinium				
Hardy Larkspur	40	40-50	High	Drops flowers readily. Injured by prolonged chilling below 40°.
Annual Larkspur	40	40-50	Very high	Short-lived regardless of temperature.
Forget-me-not	40	40-50	Very high	Short-lived. Drops petals readily. Subject to chilling injury below 40°.
Foxglove	40	32-45	Very high	Short-lived. Drops flowers readily.
Freesia	33	32-45	Low	Probably sensitive to ethylene.

Commodity	Recommended storage temp. 1/	Permissible range for 48 hrs. 2/	Perishability 3/	Remarks
	°F.	°F.	Rating	
Gaillardia	40	40-50	High	Drops petals readily. Injured by prolonged chilling below 40°.
Gardenia	45	32-50	Moderate	Shipped commercially in vented cellophane enclosed carton. Petals sensitive to drying and slight bruising.
Ginger	55	50-55	Moderate	Subject to aging and mold at high temperature. Readily bruised. Injured by prolonged chilling below 55°.
Gladiolus	35	32-55	Low	Dissipation of heat produced by product may be necessary. Tends to curve upward when packed flat.
Godetia	50	32-60	Low	Should present no special problems.
Heliconia	55	55-60	Moderate	Mold at high temperature and browning at temperatures below 55°. Ventilated shipping cases desirable.
Heath	40	32-50	Moderate	Dissipation of vital heat may be necessary.
Hyacinth	33	32-50	Low	Probably sensitive to ethylene.
Iris	35	32-50	Moderate	Should present no special problems.
Lily	35	32-50	Low	Should present no special problems.
Lily-of-the-valley	40	32-50	Moderate	Probably sensitive to ethylene. Protect bunches with wax paper.
Lupine	40	40-50	High	Drops flowers readily. Injured by prolonged chilling below 40°.
Narcissus	33	32-45	Low	Should present no special problems.
Orchid Cattleya	45	45-50	High	Shipped commercially with stems in vial of water.

Commodity	Recommended storage temp. 1/	Permissible range for 48 hrs. 2/	Perishability 3/	Remarks
	°F.	°F.	Rating	
Orchid(Cont.)				
Vanda	55	50-60	High	Shipped commercially in sealed moistureproof bags containing absorbent for ethylene.
Peony	35	32-50	Low	Dissipation of vital heat may be necessary.
Phlox	40	32-50	Very high	Short-lived. Drops flowers readily.
Poinsettia	50	45-60	High	Maintenance of constant temperature desirable.
Primrose	40	40-50	Very high	Short-lived regardless of temperature.
Ranunculus	40	32-55	High	Short-lived. Drops petals readily.
Rose	35	35-45	High	Must be kept cool. Sensitive to ethylene and injured by chilling below 35°.
Snapdragon	40	40-50	High	Short-lived. Injured by prolonged chilling below 40°. Tends to curve upward when packed flat.
Statice	35	32-55	Low	Should present no problems. Can be dried without losing color or shape.
Stevia	40	40-50	Very high	Short-lived regardless of temperature.
Stock	40	35-45	High	Avoid crowding, provide ventilation to dissipate heat produced by product. Foliage packed wet may decay. Flowers tend to curve upward when packed flat. Injured by prolonged chilling below 40°.
Strawflower	35	32-55	Low	Should present no problems. Can be dried without losing color or shape.

Commodity	Recommended Storage temp. 1/ °F.	Permissible range for 48 hrs. 2/ °F.	Perishability 3/ Rating	Remarks
Sweet pea	40	40-50	Very high	Short-lived regardless of temperature.
Sweet William	45	32-50	Moderate	Should present no special problems.
Tulip	33	32-50	Low	Should present no special problems.
Violet	33	32-40	High	Short-lived. Desirable to wrap bunches with oiled paper.
Florists' Greens and Foliage				
Croton	40	40-55	High	Needs high humidity. Dissipation of heat produced by product may be necessary.
Fern				
Asparagus	40	32-45	High	Should present no special problems.
Brake	32	32-55	Low	Should present no special problems.
Smilax	40	32-45	High	Should present no special problems.
Stag-horn	55	50-60	Moderate	Needs high humidity. Dissipation of vital heat may be necessary.
Holly	32	32-55	Low	Sensitive to ethylene. Leaves drop readily in dry air.
Huckleberry	32	32-55	Low	Should present no special problems.
Mountain laurel	32	32-55	Low	Should present no special problems.
Philodendron	45	45-55	Moderate	Needs high humidity and protection from bruising.
Picta	55	50-60	High	Needs high humidity. Dissipation of heat produced by product may be necessary.
Pothos	55	50-60	High	Covering stems with wet paper desirable. Dissipation of heat produced by product may be necessary.

Commodity	Recommended storage temp. 1/ °F.	Permissible range for 48 hrs. 2/ °F.	Perishability 3/ Rating	Remarks
Ti (palm-lily)	40	40-60	High	Needs high humidity. Dissipation of heat produced by product may be necessary.